2012

Mini-Solar Power Station

User's Manual

This document provides detailed instructions and pictures for operation of the Solar Collector and Sun Simulator hardware and software.

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Introduction

This document provides instructions and pictures for the operation of the Solar Collector and Sun Simulator hardware and software. Please read through this instruction manual before operating the Solar Collector and Sun Simulator to prevent damage to the system and/or personal physical damage.

Project Summary

The Mini-Solar Power Station consists of two subprojects. The first subproject, known as the Solar Tracker, is a satellite tracking system containing a satellite dish covered with a reflective Mylar material, but is also convertible such that a solar panel can be easily installed. The Solar Tracker will track the sun ensuring that a maximum amount of sunlight will be collected at all times. The second subproject is the Sun Simulator which is a mechanical fixture containing a heat/light source to simulate the rising, setting, and latitudinal movements of the sun. The Sun Simulator is used in correspondence with the above-mentioned Solar Tracker and serves as a testing device to prepare the Solar Tracker for operation outside.

Solar Tracker

The Solar tracker provides a platform which will have the following basics functions:

- Track the sun at a 90 degree angle at all-time throughout the day
- Shuts off automatically when light intensity is below a set threshold, and turn back on when light intensity rises back up.

We can attach anything system on this platform that requires facing the sun at a right angle. For our senior design project, we intended to use this platform for either a solar panel or a satellite dish system. The solar panel is used to collector sunlight and charge a 12V battery. The satellite dish is used to convert sunlight into heat and release the heat through a heat exchanger for experimental purposes.

Solar Panel System

The solar panel system is intended to be self-sustaining; meaning the energy collected will charge a 12-volt battery which will run the solar tracker system. This will be accomplished by having one battery (charged) run the system, and one battery being charged in the process. The batteries will be interchanged when necessary. The charged battery will also run a 300-watt inverter so common household appliances can be used.

Satellite Dish System

The satellite dish system contains a satellite dish covered with a reflective Mylar material installed on the Solar Tracker. As the Solar tracker tracks the sun the reflective Mylar material will focus all the sunlight to the dish's focal point. A hollow copper coil tube, which contains continuously running fluid, will be placed at the focal point. As the sunrays are reflected and focused at the copper coil tube, essentially at one point, the copper coil will begin to heat up which will consequently heat the fluid

inside the coil. Thermal insulated tubing will connect the copper coil to the heat exchanger and a tank reservoir, so that the heat from the liquid can be measured. The system is powered using a charged 12-volt battery.

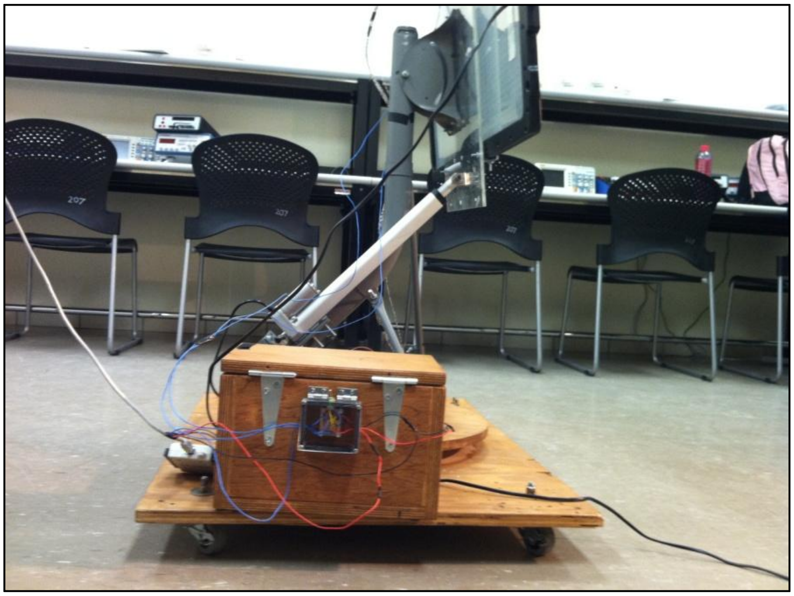

Figure 1: Solar Collector with Solar Panel Installed

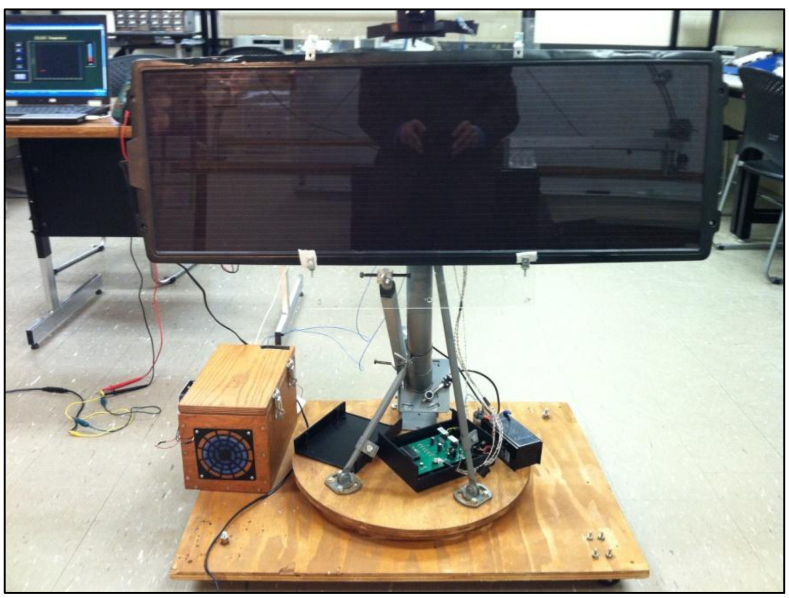

Figure 2: Solar Collector with Solar Panel Installed

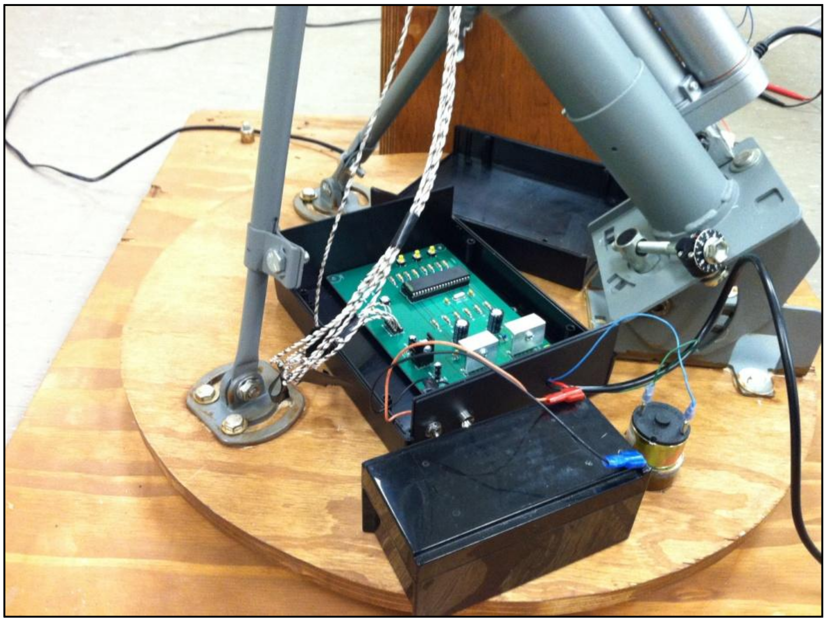

Figure 3: Solar Collector PCB, PCB Enclosure, and Battery

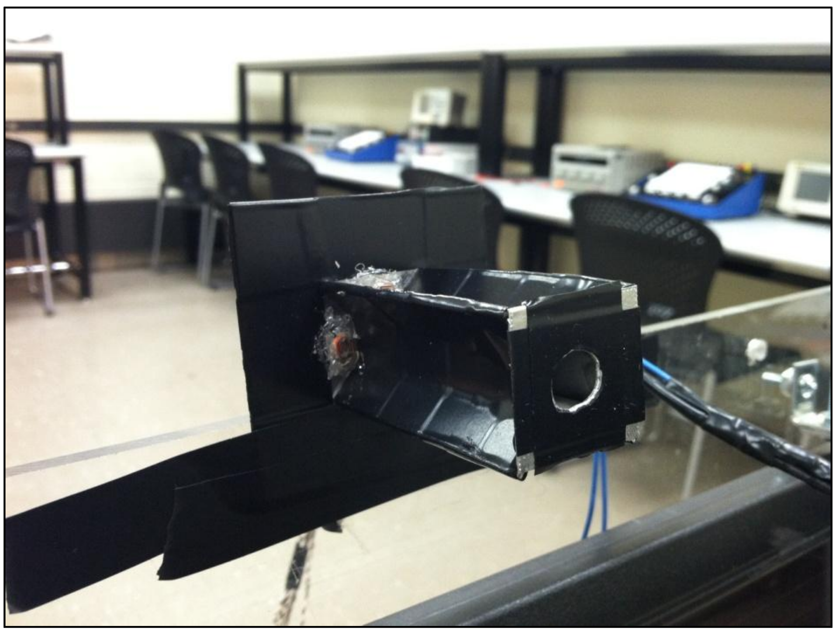

Figure 4: Solar Collector Sensor

Solar Tracker Operation

It is very simple to operator this system once the solar panel is installed on the platform. The only operation button is the power switch on the PCB enclosure; the power indicator will indicate whether the system is turned on or not. Once it is turned on, it will start its full automatic operations and track the sun at all time.

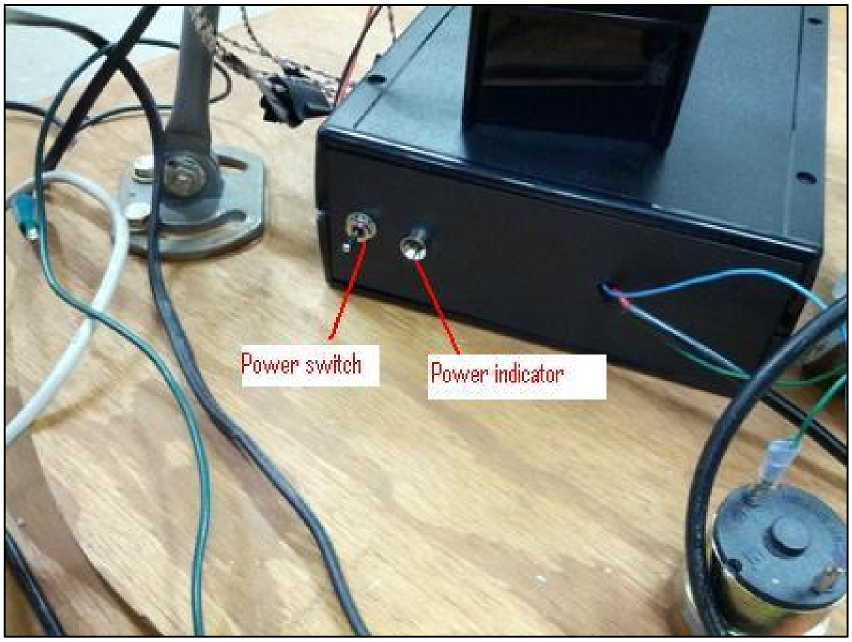

Figure 5: Power switch and power indicator

Both the solar panel and satellite dish can be mounted on the platform provided on the solar tracking system. The solar panel is connected to a voltage regulating recharging circuit to charge a 12V battery, and the satellite dish is connected to a heat exchanger. Both will be shown in the next sections.

Figure 6: Solar tracker platform

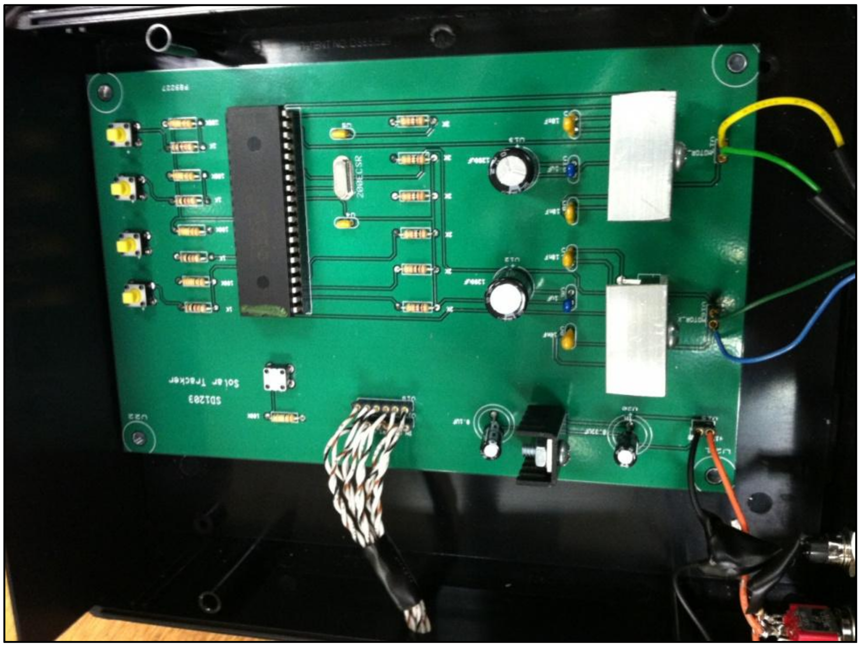

Figure 7: Solar Collector PCB

Heat Exchanger

The heat exchanger is used to contain and measure the heat generated with the satellite system attached. As the water is heated the coil inside the box begins to heat which in turn heats the inside of the box through the process of convective heat transfer. Using a NI USB 6008 DAQ, the temperature data will be plotted in real time using LabVIEW.

Heat Exchanger Operation

Before using the heat exchanger, verify all hardware and software are properly connected. Before operation verify the DAQ is properly connected the heat exchanger circuit by verifying the ground wire (black wire) is connected to port 1, the +5V wire (red wire) is connected to port 31, and the analog input wire (blue wire) is connected to port 2. Please refer to figure 8 for the DAQ pinout.

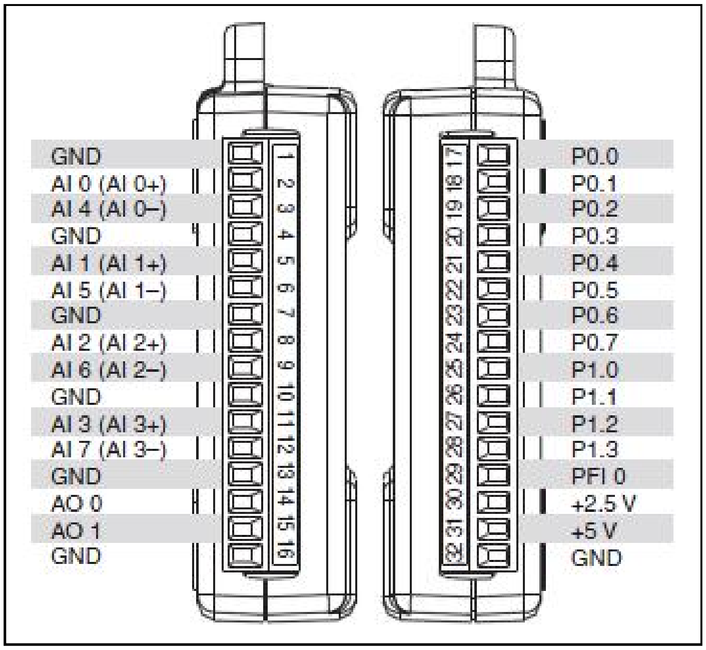

Figure 8: NI USB DAQ6008 Pinout

The DAQ provides +5V (pin 31) to power the heat exchanger circuit. This only occurs when the DAQ is plugged into the computer USB port. The power to the heat exchanger circuit can be turned “on” and “off” using the toggle switch. When the heat exchanger circuit is “on” the green LED light will be illuminated. Figure 9 displays the heat exchanger enclosed circuit, toggle switch, and green LED.

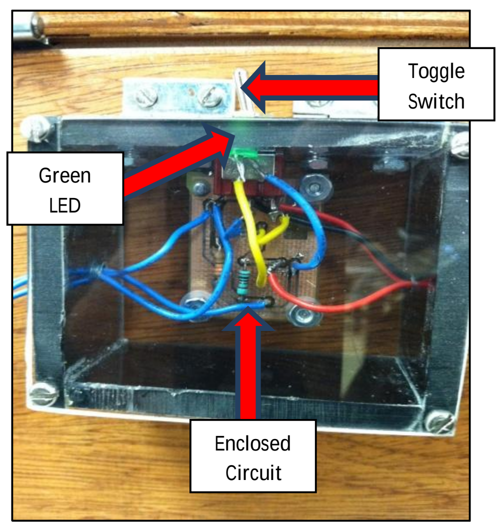

Figure 9: Heat Exchanger Circuit, Toggle Switch, and Green LED

Figure 10 displays the LabVIEW front panel which is the user interface. The following descriptions describe the operation of the front panel. A short description is also provided on figure 10.

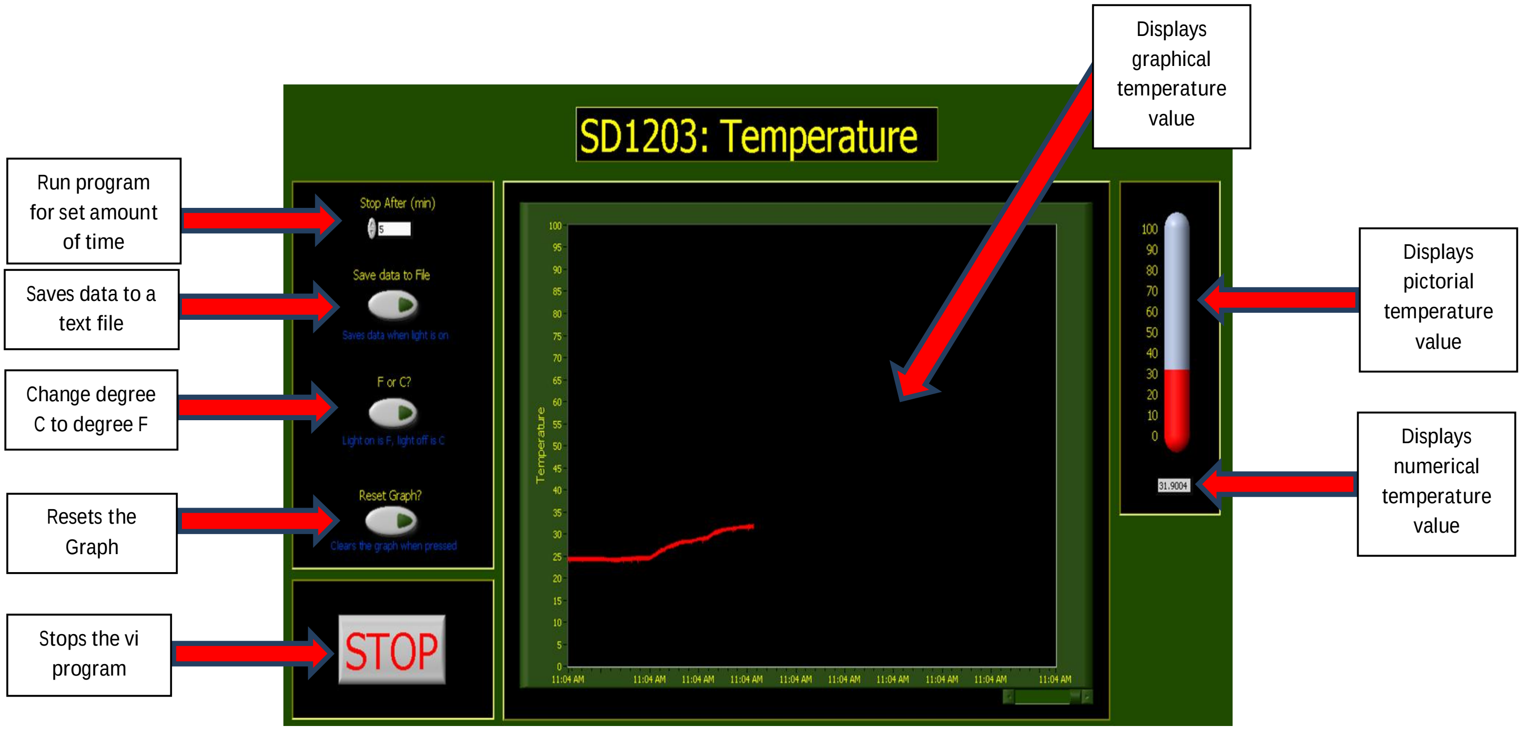

Figure 10: LabVIEW Front Panel

Stop After (min): The “Stop After (min)” control is a program timer that executes for the duration set by the user. For example, if the user enters “10” the program will execute for 10 minutes. When the program is initially opened the default “Stop After (min)” is set to zero, so this must be updated before the simulation begins.

Save data to file: The “Save data to file” button allows the user to save the current data being generated to a tab delimited text file. This file can then be saved and opened in Excel. This button is similar to an on and off light switch. When the button has not been pressed the green light is off, and when the button is pressed the green light is on and data will subsequently be saved. Data can be saved at any time while the program is running. However, the data is saved to only one file. For example, if you press the button to save data this data will be saved to the file. If the button is pressed again to turn off the saving data option and then pressed again the new data will overwrite your previous data. So if you want to save data from multiple runs you have to “save as” the data file to a new name. When the program is initially opened the default “Save data to file” is off, so if you want to save the data to the file you must select the button (the green light will turn on).

F or C?: The “F or C?” button changes the temperature reading from degrees Celsius to degrees Fahrenheit. This button is similar to a on and off light switch. When the program is initially opened the default “F or C?” is such that degrees Celsius is displayed, so if you want to display degrees Fahrenheit you must select the button (the green light will turn on).

Reset Graph?: The “Reset Graph?” button resets the graph when the button is pressed. This button resets to the off state (green light off) once the graph is cleared. Thus, the graph can be

cleared multiple times during a run. When the program is initially opened the default "Reset Graph?" is off, so if you want to clear the graph you must select the button (the green light will turn on), once the graph is cleared the green light will turn off.

Figure 11 displays the LabVIEW block diagram merely for documentation and illustration.

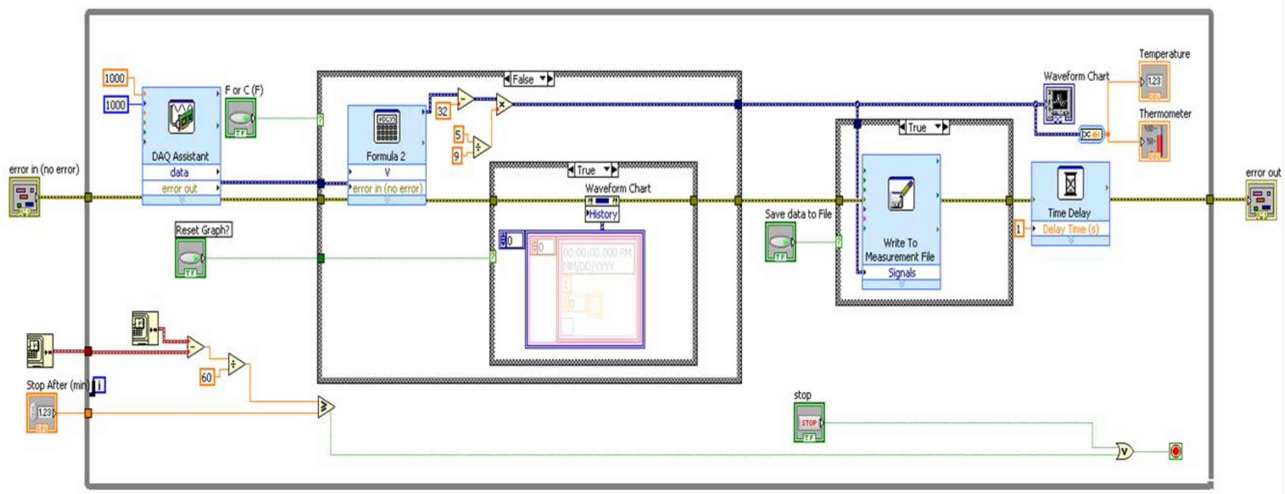

Figure 11: LabVIEW Block Diagram

Battery Charger

We used a buck-boost IC to build a recharger system. This system can serve the Solar Tracker because the Solar Tracker needs a DC voltage supply. Figure 12 is the schematic of the recharger system. The Buck-boost IC can supply a stable voltage to charge the battery. The only problem is the design uses the MC33063A IC, which will only work when the supply voltage is higher than 3V. This supply voltage is provided from the solar panel. As we know, we cannot make sure the voltage supply is greater than 3V because the intensity of illumination outside is uncontrollable. A diode was added between the battery and the voltage output to prevent the current from flowing back into the system, causing damage to the system. The output voltage was designed to be 14.5V, providing an output current of about 0.225A. The range of the MC33063A IC input voltage is large, ranging from 3V to 40V. This system is easy to modify when different output voltages are needed, because the output value is only dependant on R1 and R2 (refer to equation 1).

Equation 1: Output Voltage of the Charger Circuit

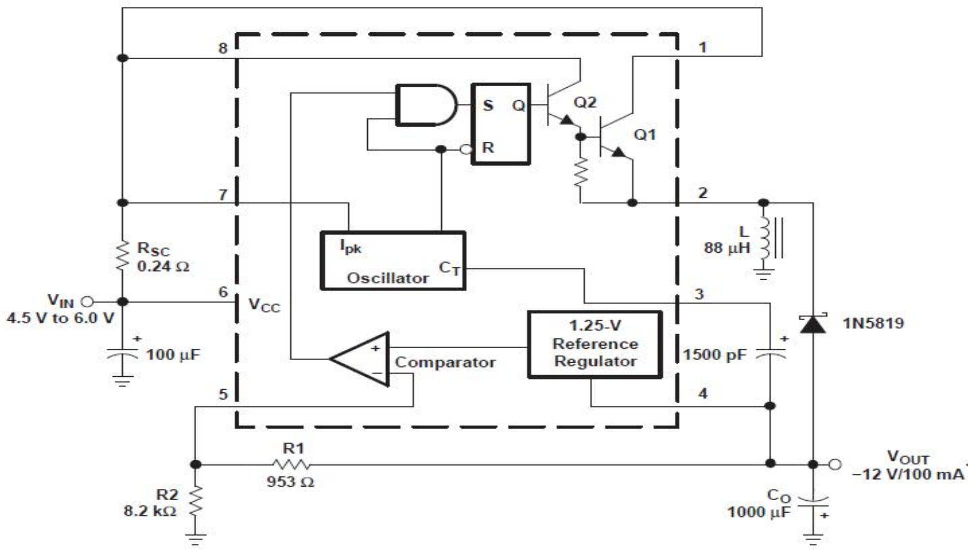

Figure 12: Charger Circuit Schematic

Sun Simulator

The mechanical fixture is composed of $\frac{3}{8}$" steel pipe, a combination of pulleys, stepper motor, and a linear actuator to drive the heat bulb to mimic the suns movement. A 250W infrared heat lamp is used to represent the sun and will be the source of heat. A dimmer switch is used with the heat lamp, which dims the heat lamp to represent cloud cover. The dimmer switch is controlled using a PIC microcontroller and Pulse Width Modulation (PWM). As stated above, temperature data is collected and plotted in LabVIEW. With the dimming of the lamp, a decrease in temperature should be evident in the LabVIEW plotted data. Both motor control and dimmer switch is controlled by a PIC microcontroller, and the programming was done in C. Figure 13 displays the Sun Simulator and all of it components.

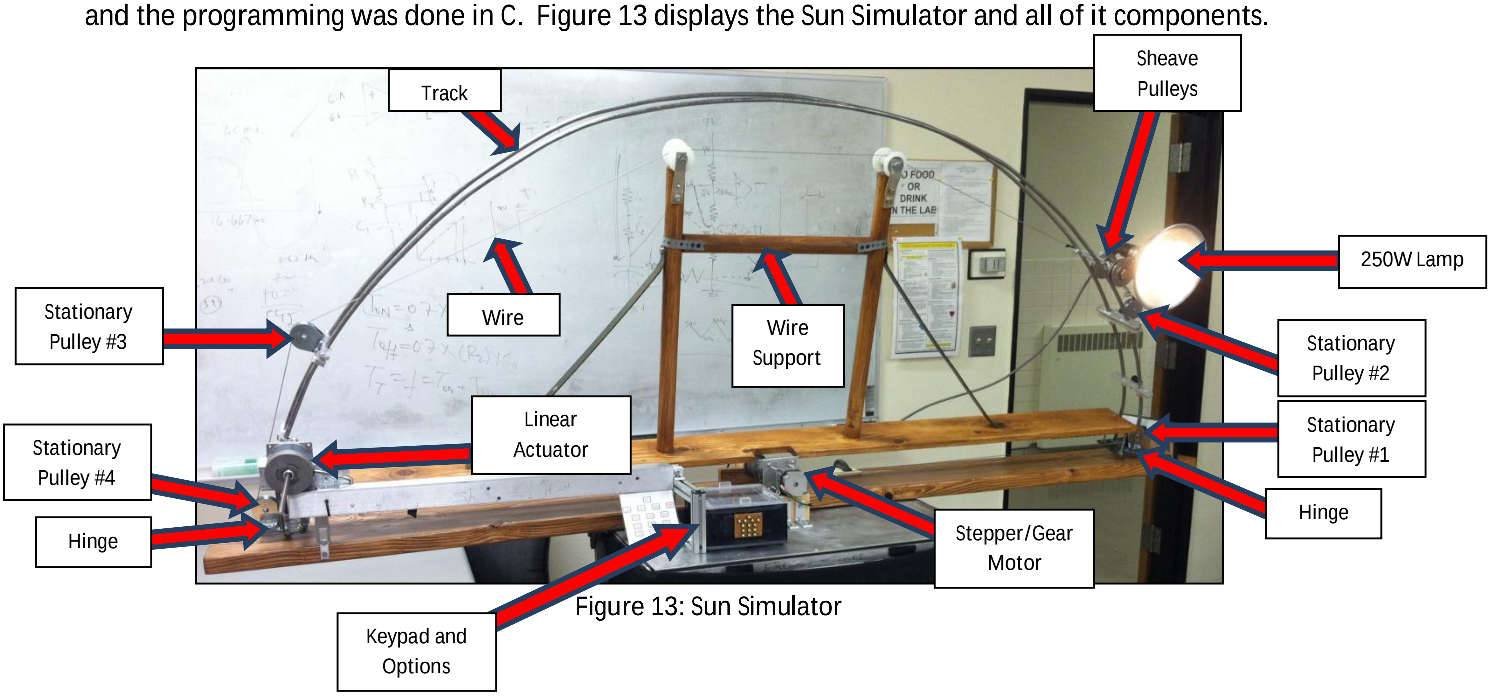

Figure 13: Sun Simulator

Sun Simulator Operation

Power

First, locate the power source on the cart behind the black curtain. The first time using the simulator, make sure the Sun Simulator is NOT connected to the power source. Once the simulator is removed, turn on the power source by pressing the green power button. When the power is "on" verify the voltage level is set to +5V. When the power supply voltage is not set to +5V, turn the voltage knob to set the power supply to +5V. Once the power supply is set to +5V turn the power supply off and re-connect the Sun Simulator. Once connected turn the power supply back "on" and now the Sun Simulator is ready to simulate. NOTE: The Sun Simulator PCB can only run with +5V, voltages higher than +5V may damage the PCB.

Motor Operation

The Sun Simulator motors are operated from the keypad located on the PCB enclosure. Keypad options are located directly to the left of the keypad, please see figure 14.

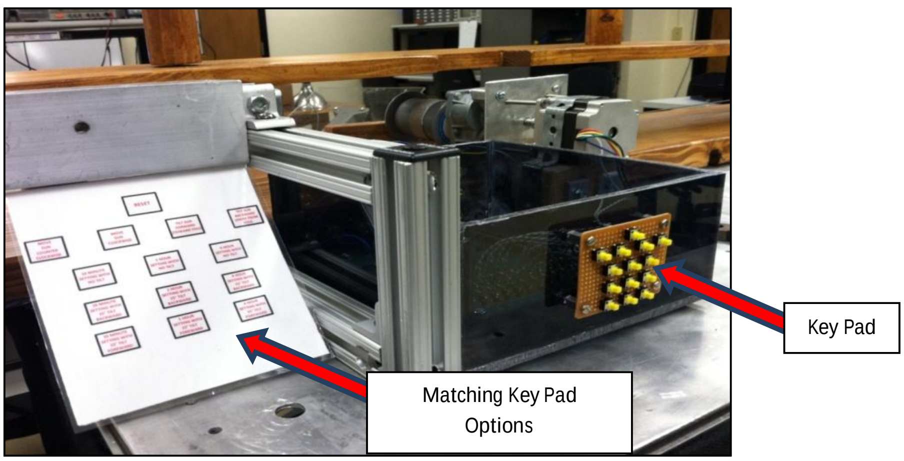

Figure 14: Key Pad and Key Pad Options

NOTE: The Sun Simulator lamp starting position must always start on the right (when facing the simulator front). Verify the black electrical tape is directly over "stationary pulley #2." This movement represents the sun rising in the east and setting in the west. If this is not verified on the initial run, the sheave pulley will go beyond "stationary pulley #3" and could potentially damage the simulator. Please refer to figure 13 for locations of stationary pulleys.

In a similar fashion, if you plan to use a preset option involving a tilt you must verify the track is completely vertical in the starting position (90° on the protector display, see figure 15). Failure to do this could cause damage to the track and/or linear actuator.

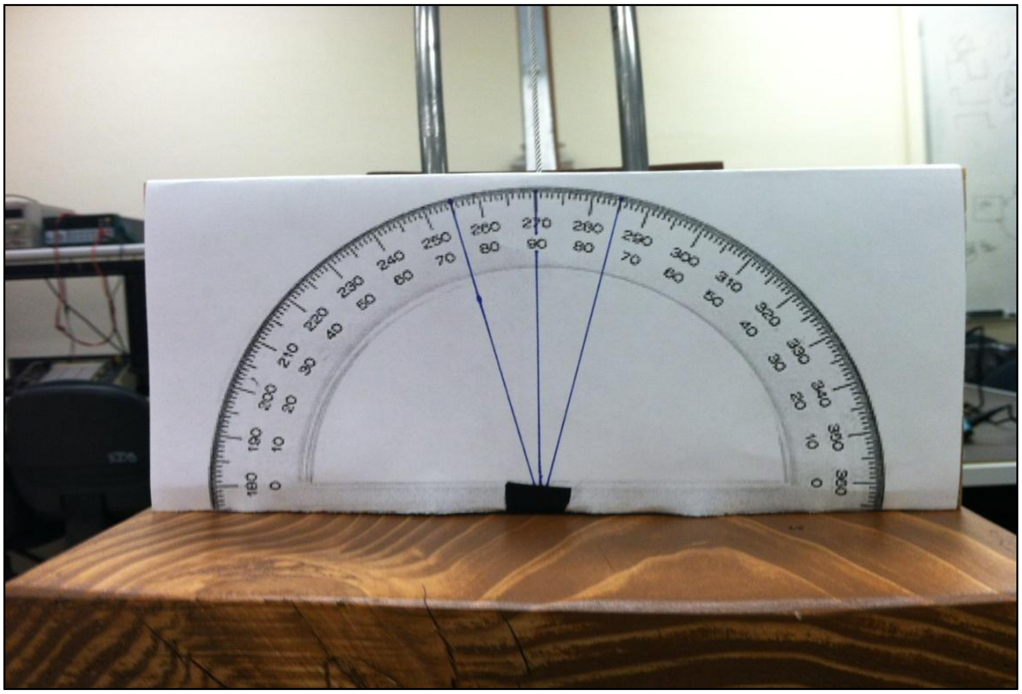

Figure 15: Sun Simulator track in starting position, no tilt

Figure 16 is the keypad options, a description of each option is provided below.

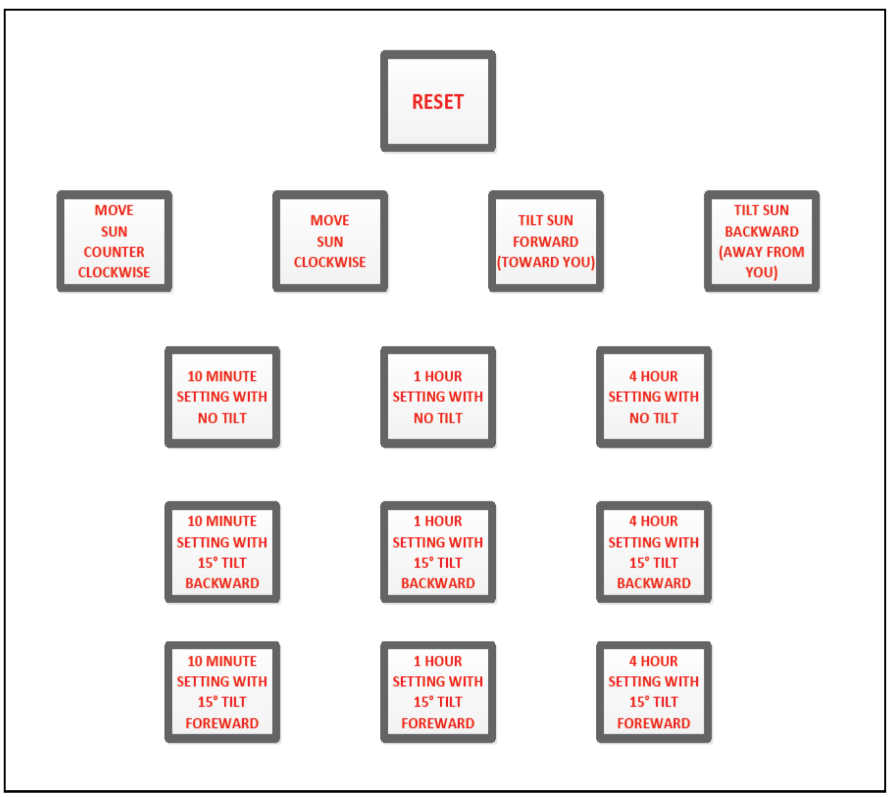

Figure 16: Sun Simulator Key Pad Options

RESET: Pressing the "RESET" button resets the microcontroller. If the reset button is pressed during a run, the lamp will have to be manually moved (using the manual buttons described next) back to the beginning before another run is started. Refer to the note above.

MOVE SUN SIMULATOR CLOCKWISE: If facing the Sun Simulator front, pressing this option moves the lamp to the right (sun moving west to east). This button is often used to manually move the lamp to the beginning position if reset is pressed or the power was turned off.

MOVE SUN SIMULATOR COUNTERCLOCKWISE: If facing the Sun Simulator front, pressing this option moves the lamp to the left (sun moving east to west).

TILT SUN FORWARD (TOWARD YOU): This option tilts the track towards you, if you are facing the front of the simulator.

TILT SUN BACKWARD (AWAY FROM YOU): This option tilts the track away from you, if you are facing the front of the simulator.

10 MINUTE SETTING WITH NO TILT: This preset option runs the lamp (sun) right to left (east to west) in a 10 minute interval. This option does not tilt the track, so this option can be run if the track is already tilted. NOTE: This option requires the lamp to be in the starting position.

1 HOUR SETTING WITH NO TILT: This preset option runs the lamp (sun) right to left (east to west) in a 1 hour interval. This option does not tilt the track, so this option can be run if the track is already tilted. NOTE: This option requires the lamp to be in the starting position.

4 HOUR SETTING WITH NO TILT: This preset option runs the lamp (sun) right to left (east to west) in a 4 hour interval. This option does not tilt the track, so this option can be run if the track is already tilted. NOTE: This option requires the lamp to be in the starting position.

10 MINUTE SETTING WITH 15° TILT BACKWWARD: This preset option first tilts the track (sun) 15° backwards (away from you) and then runs the lamp (sun) right to left (east to west) in a 10 minute interval. NOTE: This option does tilt the track, so this option must have the track in the starting position, please see figure 15.

1 HOUR SETTING WITH 15° TILT BACKWWARD: This preset option first tilts the track (sun) 15° backwards (away from you) and then runs the lamp (sun) right to left (east to west) in a 1 hour interval. NOTE: This option does tilt the track, so this option must have the track in the starting position. NOTE: This option requires the lamp to be in the starting position, please see figure 15.

4 HOUR SETTING WITH 15° TILT BACKWWARD: This preset option first tilts the track (sun) 15° backwards (away from you) and then runs the lamp (sun) right to left (east to west) in a 4 hour interval. NOTE: This option does tilt the track, so this option must have the track in the starting position. NOTE: This option requires the lamp to be in the starting position, please see figure 15.

10 MINUTE SETTING WITH 15° TILT FOREWARD: This preset option first tilts the track (sun) 15° forwards (towards you) and then runs the lamp (sun) right to left (east to west) in a 10 minute interval. NOTE: This option does tilt the track, so this option must have the track in the starting position. NOTE: This option requires the lamp to be in the starting position, please see figure 15.

1 HOUR SETTING WITH 15° TILT FOREWARD: This preset option first tilts the track (sun) 15° forwards (towards you) and then runs the lamp (sun) right to left (east to west) in a 1 hour interval. NOTE: This option does tilt the track, so this option must have the track in the starting position. NOTE: This option requires the lamp to be in the starting position, please see figure 15.

4 HOUR SETTING WITH 15° TILT FOREWARD: This preset option first tilts the track (sun) 15° forwards (towards you) and then runs the lamp (sun) right to left (east to west) in a 4 hour interval. NOTE: This option does tilt the track, so this option must have the track in the starting position. NOTE: This option requires the lamp to be in the starting position, please see figure 15.

Dimmer

The dimmer switch is used in combination with a 250W infrared heat lamp which represents the sun and is the source of heat for the sun simulator. This switch allows the user to both dim and brighten the light, representing varying amounts of cloud cover. Therefore, this function allows the user to output varying amounts of heat.

The dimmer switch is controlled using a PIC microcontroller and Pulse Width Modulation (PWM). All programming for this function was done in C. By varying the Pulse Width Modulation output from the PIC microcontroller, the user is able to set the brightness of the heat lamp to the desired level and also simulate gradual increases and decreases in brightness.

Dimmer Operation

The Dimmer Switch is operated using a keypad on the PIC microcontroller. The display screen on the PIC microcontroller allows the users to see how much of the total brightness is being outputted by the heat lamp. When turned on, the display will read "PWM = 0.00" and the light will be fully on. "PWM = 0.00" represents that the light is 0% bright. NOTE: "PWM = 1.00" represents that the light is 100% dim; this occurs when the light is completely off.

Each keypad option is provided below:

YELLOW: Pressing the yellow button on the PIC microcontroller resets the PIC and allows the user to initialize the Dimmer Switch program. This button must be pressed before the user is able to operate the dimming switch.

RB0: Pressing RB0 incrementally brightens the heat lamp by 5%. Each time this button is pressed, the light will become 5% brighter. If you reach 100% brightness, the output screen will display "PWM =

0.00". This indicates that the light has reached its full potential and pressing R0 will no longer do anything to the light.

RB1: Pressing RB1 incrementally dims the heat lamp by 5%. Each time this button is pressed, the light will become 5% more dim. If you reach 100% dim, the output screen will display "PWM = 1.00". This indicates that the light has fully turned off and pressing RB1 will no longer do anything to the light.

RB2: Pressing RB2 brightens the light incrementally at 1% per 0.1 seconds until the light has become 100% bright. At this point the light will stay fully on until another button is pressed. This button can be pressed at any point in time no matter how bright the light is. It will always start increasing in brightness from the level it was at when RB2 was pressed.

RB3: Pressing RB3 dims the light incrementally at 1% per 0.1 seconds until the light has become 100% dim. (It will be completely off.) At this point the light will stay fully off until another button is pressed. This button can be pressed at any point in time no matter how bright the light is. It will always start decreasing in brightness from the level it was at when RB3 was pressed.

RB4: Pressing RB4 brightens the light incrementally at 1% per second until the light has become 100% bright. At this point the light will stay fully on until another button is pressed. This button can be pressed at any point in time no matter how bright the light is. It will always start increasing in brightness from the level it was at when RB4 was pressed.

R5: Pressing RB5 dims the light incrementally at 1% per second until the light has become 100% dim. (It will be completely off.) At this point the light will stay fully off until another button is pressed. This button can be pressed at any point in time no matter how bright the light is. It will always start decreasing in brightness from the level it was at when RB5 was pressed.

Summary

The goal of this project was to create a functional solar tracking system that is operational outside using natural sunlight. With the Mylar reflective material, the reflected sun energy will heat liquid running through a copper coil connected to a water reservoir. Temperature data will be plotted real time using LabVIEW, so decrease in temperature due to cloud cover should be easily recognizable. When the solar panel is installed, using the energy obtained a buck/boost battery charger will charge one 12-volt rechargeable battery. A second battery (already charged) will power a 300-watt inverter, which will allow for use of household appliances.